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Evolution of the "Drivers" of Translational Cancer Epidemiology: Analysis of Funded Grants and the Literature

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Abstract

Concurrently with a workshop sponsored by the National Cancer Institute, we identified key "drivers" for accelerating cancer epidemiology across the translational research continuum in the 21st century: emerging technologies, a multilevel approach, knowledge integration, and team science. To map the evolution of these "drivers" and translational phases (T0–T4) in the past decade, we analyzed cancer epidemiology grants funded by the National Cancer Institute and published literature for 2000, 2005, and 2010. For each year, we evaluated the aims of all new/competing grants and abstracts of randomly selected PubMed articles. Compared with grants based on a single institution, consortium-based grants were more likely to incorporate contemporary technologies ($P = 0.012$), engage in multilevel analyses ($P = 0.010$), and incorporate elements of knowledge integration ($P = 0.036$). Approximately 74% of analyzed grants and publications involved discovery (T0) or characterization (T1) research, suggesting a need for more translational (T2–T4) research. Our evaluation indicated limited research in 1) a multilevel approach that incorporates molecular, individual, social, and environmental determinants and 2) knowledge integration that evaluates the robustness of scientific evidence. Cancer epidemiology is at the cusp of a paradigm shift, and the field will need to accelerate the pace of translating scientific discoveries in order to impart population health benefits. While multi-institutional and technology-driven collaboration is happening, concerted efforts to incorporate other key elements are warranted for the discipline to meet future challenges.

Keywords

cancer; cancer epidemiology; collaboration; consortia; epidemiologic methods; knowledge integration; translation

We have previously observed that epidemiology is at the cusp of a paradigm shift—propelled by a need to accelerate the pace of translating scientific discoveries to impart population health benefits (1). As part of a National Cancer Institute (NCI)-Epidemiology

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and Genomics Research Program (EGRP) strategic planning effort to transform the practice of epidemiology in the 21st century, we identified a set of overarching "drivers" that can influence translational cancer epidemiology: 1) collaboration and team science; 2) emerging technology; 3) a multilevel approach; and 4) knowledge integration from basic, clinical, and population sciences (1).

Details related to each driver have been described elsewhere (1). In brief, the complexity and scope of cancer epidemiology research requires thoughtful team science initiatives across multiple disciplines (e.g., epidemiology, clinical medicine, statistics, environmental health, genomics, behavioral and social science, and health economics). This can be achieved, in part, by consortia of well-characterized cohort and case-control studies. Emerging technologies could facilitate better characterization of genomic background and exposures, as well as their interactions. A multilevel approach entails analyses and interventions that incorporate individual- and biological-level factors with macroenvironment-level factors to enhance the investigation of complex diseases (2, 3). Lastly, knowledge integration has been used with different definitions and perspectives (4–6); for the present review, we adopted the definition that includes knowledge management, knowledge synthesis, and knowledge translation (7). Collectively the 3 processes provide a methodological framework for knowledge integration, which aims to maximize the use of collected scientific information to accelerate the translation of discoveries into individual and population health benefits and to identify scientific gaps that warrant further research (7).

We sought to obtain a snapshot of the types of studies being conducted in cancer epidemiology with respect to the "drivers" of such research in the first decade of the 21st century. Towards this goal, we undertook a systematic analysis of epidemiology-related grants funded by the NCI's Division of Cancer Control and Population Sciences (DCCPS) and Division of Cancer Prevention (DCP) to assess the evolution of the identified "drivers" and the prevalence of translational cancer research in grants awarded through the NCI for the years 2000, 2005, and 2010. We performed the same analyses for a randomized sample of published literature across the 3 time periods. Here, we describe the results of the trends analysis of NCI-funded grant applications and peer-reviewed papers generated by the cancer epidemiology community and discuss the implications of our findings.

METHODS

Sampling frame for NCI grants

We focused our sampling frame on grants funded through the DCCPS and the DCP because collectively they represent a comprehensive selection of cancer epidemiology research supported by the NCI. The DCCPS and the DCP are 2 extramural divisions of the NCI. The DCCPS has the lead responsibility at NCI for supporting research in surveillance, epidemiology, health services, behavioral science, and cancer survivorship (http://cancercontrol.cancer.gov/). Within the DCCPS, the EGRP is one of the largest funders of cancer epidemiology research in the United States (http://epi.grants.cancer.gov/). The DCP supports extramural research that generates new information about 1) molecular processes that are amenable to intervention, 2) developing effective chemo-prevention agents, 3)

discovering early detection biomarkers, 4) pinpointing mechanistically targeted nutrients, 5) testing new screening methods and technologies, and 6) conducting phase I, II, and III clinical trials in prevention and control (http://prevention.cancer.gov/).

Search for and selection of NCI grants

All grants funded through the DCCPS and DCP in the years 2000, 2005, and 2010 were analyzed. We used the NCI's Portfolio Management Application software (version 13.4), which mines the National Institutes of Health IMPAC II database (http://era.nih.gov). We included only new and competing renewal grants for each year, regardless of funding mechanism. Because the focus of our analysis was to examine the evolution of the "drivers" in cancer epidemiology research, we included all grants awarded by the EGRP, whose mission is to fund research in human populations to further understanding of the determinants of cancer occurrence and its outcomes. For the other DCCPS programs and for DCP, we selected grants awarded for carrying out human studies with cancer-related endpoints. We excluded grants for studies that used animal models or cell lines or intervention studies with endpoints not related to cancer. Five coders performed the coding for the grants through a systematic review of the grant application's abstract and specific aims. When needed, a review of the full grant application was conducted.

Literature search

We developed a specialized query (see Appendix) to search the PubMed database (National Library of Medicine, Bethesda, Maryland) for published studies related to cancer epidemiology. For the present project, our search algorithm was restricted to human studies described in English-language articles that included an abstract. We applied the search query for the years 2000, 2005, and 2010 separately. Three coders were assigned to each year, and each coder independently reviewed abstracts to identify the first 100 randomly selected cancer epidemiology publications in the assigned year. For our purposes, eligible studies must have had a cancer-related endpoint and a sample size of ≥100 cases. We excluded primary clinical trials but included meta-analyses of them. The first 100 cancer epidemiology studies identified for each of the years 2000, 2005, and 2010 were then compiled to form the 300 randomly selected publications for further coding.

Coding of grants and literature

Selected grants and publications were coded with regard to 5 key "drivers" and respective subcategories, as follows.

1. *Emerging technology*. Studies were assigned to the following technology subcategories: 1) *none* for studies using traditional exposure measurement tools (e.g., paper-based questionnaires); 2) *single nucleotide polymorphism genotyping* associated with candidate gene association studies and *high-throughput genotyping* associated with genome-wide association studies (GWAS); 3) *other* "*-omics*"-*related technologies* (e.g., proteomes, telomere characteristics, methylation, mitochondrial DNA, micro-RNA, metabolomes); 4) *novel technologies* (studies that used geographic information systems or geospatial data or that incorporated/developed novel statistical models, methods, or assays); and 5) *other studies* (e.g.,

Web-based exposure assessment tools, imaging technology). These a priori subcategories were identified as those that have changed the landscape of epidemiologic research in the past decade.

2. *Translational phases*. Studies were assigned to the following subcategories: *none*, *T0 phase* for research that was etiological in nature (e.g., association studies), *T1 phase* for research that characterized the health application of a scientific discovery, *T2 phase* for studies that evaluated the health application to inform development of a guideline, *T3 phase* for studies that researched the implementation, dissemination, or adaptation of the distribution of a tested intervention in different contexts, and *T4 phase* for studies that researched outcomes. Definitions of the phases of translation were derived from the work of Khoury et al. (8, 9) and modified appropriately for epidemiologic studies.

3. *A multilevel approach*. Subcategories included *none* for studies that examined a single exposure, *gene-environment* for studies that investigated the interplay between genes and modifiable risk factors, and *other* for studies that incorporated behavioral factors, social constructs, or geocoding factors into the model.

4. *Knowledge integration*. Subcategories included *none*, *systematic review/meta-analysis*, and *other* for studies that included guideline development or development of tools, models, or databases. Both systematic reviews and meta-analysis were used as indicators of knowledge synthesis, a component of knowledge integration, which captures the integration of existing epidemiologic research on a particular topic (7). Development of guidelines and databases are broad indicators of knowledge management and knowledge translation (7).

5. *Collaboration/team science*. Studies were assigned to the following subcategories: *none* for single-institution case-control studies, case series, or family studies; *cohort* for studies using prospectively collected data from a single institution; and *consortia* for studies (case-control and/or cohort) formed through collaboration between multiple institutions (10).

Coders determined whether studies included any of the 5 broad categories and then assigned them to the appropriate subcategories. To minimize intercoder discrepancies in the literature, each coder reviewed one-third of the coding results for each of the other 2 years. Grants identified from each year were coded similarly with regard to the 5 areas and respective subcategories as described above. Additionally, the 4 primary coders reviewed one-quarter of the coding results for the other 2 years. Any disagreements were discussed as a group and resolved by consensus.

Statistical analyses

We created variables to represent the 5 broad “drivers.” We used consortium-based studies as an indicator of multi-institutional collaboration and by extension a surrogate for team science. We collapsed studies that used subcategories of technologies into 1 group, categorizing them as technology-driven, and compared them with those studies that did not use technologies (i.e., those that used traditional tools). Likewise, multilevel and knowledge integration variables were dichotomized into none versus yes (i.e., comprised of the

respective subcategories). We performed a modified Wilcoxon rank-sum test to examine trends across time periods (11). Exploratory analyses included investigating the relationship between collaboration (as the outcome of interest) and the remaining "drivers." Analyses using 2-sample *t* tests were performed to compare differences. We used multivariate logistic regression, adjusting for year of funding or publication date and division (DCCPS or DCP), to examine the relationship between collaboration and selected drivers. All analyses were performed using Stata, version 10 (StataCorp LP, College Station, Texas).

RESULTS

Table 1 shows the coding results for NCI-funded grants and the published literature with respect to the 5 drivers of interest and their corresponding subcategories, by year (2000, 2005, or 2010). We identified 591 cancer epidemiology–related grants funded through the 2 NCI divisions in the 3 selected years. The DCCPS funded the majority (n = 443; 75%) of the identified cancer epidemiology grants; of these, the EGRP funded 58% (n = 256), while the other DCCPS programs funded the remaining 42% (data not shown). The number of cancer epidemiology grants funded by the NCI increased between 2000 and 2005 but declined slightly between 2005 and 2010. For the published literature, we reviewed a total of 1,710 articles randomly selected from PubMed for the 3 specified years. From this random set, we identified 300 articles related to cancer epidemiology (i.e., 100 published studies per year).

Technology-driven research

Our data showed that funding of grants that incorporated contemporary technologies trended positively from 2000 to 2010 ($P_{trend} < 0.001$; Table 1). Of those that used novel technologies, molecular technologies comprised the majority. Funding for GWAS research, for which the EGRP was the major source (10 of 11 grants), increased from 0% to 5.5% between 2005 and 2010. There was also an increasing trend for grants that incorporated other "-omic" technologies ($P_{trend} < 0.001$), such as those for studies of methylation, proteomes, and mitochondrial DNA, acrossthe NCI. Funding of grants that used nonmolecular technologies also increased from 2000 to 2005 but decreased in 2010. In the 3 years evaluated, few grants incorporated current technologies, such as mobile technologies, Web-based surveys, or electronic medical records.

In the cancer epidemiology literature, the proportion of studies that incorporated newer technologies was constant. Reports of GWAS findings appeared in 2010, and a sharp increase in findings from studies using other "-omic" technologies was observed between 2005 (n = 1) and 2010 (n = 7). We observed a significant decline in the publication of findings from studies using nonmolecular technologies ($P_{trend} = 0.003$).

Translational research

Overall, 74.1% (438/591) of all funded grants were for studies in the T0 (discovery) and T1 (characterization) phases. The predominance of the discovery-characterization type of research supported by the NCI was evident in all 3 years evaluated. Although the finding was not statistically significant ($P_{trend} = 0.086$), T1 research appeared to have been trending positively in recent years, withapproximately18.6% and 16.8% of new grants being T1

grants in 2005 and 2010 as compared with 9.8% in 2000. While numbers of T2 and T3 grants appeared to be constant in the 3 years evaluated (approximately 7% per year), we observed a sizable number (n = 10; 6.1%) of T4 funded grants in 2000; however, there was a decrease in funding for these types of research in 2005 and 2010.

The literature analysis also showed that cancer epidemiology publications were predominantly (72.7%) studies in the discovery-characterization phase (T0/T1) (Table 1). In this random subset of 300 publications, approximately 6.3% were studies in the T2 phase and beyond. Among these, we identified 4 publications that encompassed elements of T4 research, that is, outcome research representing the incorporation of evidence-based practice into a population health impact (Table 1).

Multilevel research

Only 19.3% (n = 114) of NCI grants and 7.3% of published studies incorporated a multilevel approach in our data set. Of those studies using a multilevel approach, the majority (60.1% for grants and 63.6% for the literature) were restricted to gene-environment interactions across the 3 single-year periods, with no evidence of a trend (P_{trend} = 0.17). Beyond studies of gene-environment interaction, there was a decline in funded grants for studies using other types of approaches, such as studies incorporating sociocultural factors in addition to biological or lifestyle factors.

Conversely, the data showed a positive trend in the publication of gene-environment interaction research from 2000 to 2010 (P_{trend} = 0.003), with a decreasing trend in multilevel approaches using other factors beyond gene-environment interaction.

Knowledge integration–related research

Thirty-four grants (5.8% of the total for the 3 years) included some component of knowledge integration. Of these, 6 grants (1.0% of the total) specified a planned meta-analysis/systematic review (knowledge synthesis), while the remaining 28 were related to establishing database or guideline development (Table 1). While the proportions of grants incorporating knowledge synthesis (e.g., meta-analysis/systematic reviews) were marginal in the 3 single-year periods, there was a negative trend in funding of grants that related to guideline development or development of databases from disparate sources (P_{trend} = 0.001).

For the literature analysis, we observed a notable decrease in the publication of narrative reviews between 2000 (17%) and 2010 (5%) (P_{trend} = 0.013), while the proportion of systematic reviews and meta-analyses increased in the same period (P_{trend} = 0.014).

Collaborative research

Overall, our evaluation of both NCI grants and the literature showed a distinct upward trend for multi-institutional collaborations in the form of consortia (for grants, P_{trend} = 0.002; for literature, P_{trend} = 0.006). The increase in consortium-related funding may have reflected the marked rise of findings from multi-institutional collaborative studies, which increased from 0% prior to 2010 to 5% in 2010 (Table 1).

Table 2 shows the relationships between the extent of collaboration and elements of the "drivers" in NCI grants. Compared with grants that were not cohort- or consortium-based, consortium-based grants were significantly more likely to incorporate emerging technologies (adjusted for year of funding and division, odds ratio (OR) = 1.79, 95% confidence interval (CI): 1.13, 2.82; $P = 0.012$), to support multilevel approaches (adjusted for year of funding and division, OR = 2.01, 95% CI: 1.18, 3.42; $P = 0.010$), and to support knowledge integration–type activities (adjusted for year of funding and division, OR = 2.57, 95% CI: 1.06, 6.20; $P = 0.036$). For similar comparisons, cohort grants were also more likely to incorporate elements of novel technologies and multilevel approaches. For the literature analyses, we observed no difference in incorporation of technologies between cohort studies and collaborative consortium studies ($P = 0.11$).

DISCUSSION

In the present analysis, we evaluated the trends in cancer epidemiology publications and NCI-funded cancer epidemiology grants in relation to 5 characteristics or "drivers" of the field (1) for the years 2000, 2005, and 2010. Our evaluation of funded grants suggested an upward trend towards multi-institutional collaborative research and incorporation of novel technologies. For the published literature, there were significant positive trends toward consortium-based studies, systematic reviews/meta-analyses, and gene-environment studies. In the past decade, "-omic" technologies were generally the primary tools used in cancer epidemiology studies for both grants and literature. The present review has identified a critical need for more T2–T4 translational studies, multilevel analyses, and knowledge integration in the field of cancer epidemiology moving forward.

We and other investigators (1, 12, 13) have asserted that team science across disciplines and within fields is a critical component of 21st century cancer epidemiology research. Based on our review, the NCI's support for multi-institutional collaborative research increased rapidly during the past decade. Furthermore, our analyses suggested that consortium-based studies may be the scientific engine driving the transformation of cancer epidemiology (1, 13). Nevertheless, a high proportion of the consortium grants restricted the research to molecular epidemiology–related inquiries. This is not surprising, since "-omic" technologies permeated cancer research in the first decade of the 21st century and cancer consortia were established at the end of the 20th century, primarily to overcome the issue of small sample sizes in cancer epidemiology. Thus, the original purpose of consortium-based research was to pool study data together to obtain the increased statistical precision afforded by a consortium's larger sample size (14, 15) for discovery/etiological research in an era of genome-driven technologies.

The large sample sizes of consortia also explain the greater likelihood of consortia being awarded grants to engage in research using multilevel approaches, such as studies of gene-environment interaction. Nonetheless, future collaborative endeavors should move beyond genome-based studies and fully optimize the full potential of consortia. An analysis of data collected from 49 EGRP-funded cancer epidemiology consortia recently highlighted several benefits of consortium-based research (10), including opportunities to form new collaborations or research networks across national boundaries. This modern scientific

enterprise may further facilitate the rapid incorporation of emerging technologies (as demonstrated by genome-wide genotyping and next-generation sequencing) into large-sale population studies and the capacity to integrate multilevel approaches (10).

There was limited evidence that incorporation of nonmolecular technologies is on the rise in our review. This will probably change, as current and future epidemiologic research needs to incorporate advancements in digital technology (e.g., smart phones, electronic medical records, and social media) to improve exposure assessment and outcome measurement. For example, we previously highlighted the potential for technologies used in dietary assessment to shed light on the equivocal evidence related to diet and cancer (1), and Kuller et al. have commented on the importance of new technologies that permit precise measurement of host and environmental exposures in epidemiology (16).

Our evaluation further suggests a critical gap in cancer epidemiology research with regard to knowledge integration and multilevel approaches. In the present review, we defined knowledge integration as comprised of 3 complementary processes (7), and we broadly used systematic reviews and meta-analyses as indicators of knowledge synthesis (a component of knowledge integration which assesses a synthesized body of evidence) and other elements of knowledge management and translation. Our analysis of the literature corroborated a prior analysis of the biomedical literature that found a decrease in narrative reviews and a marked positive trend in the publication of systematic reviews and meta-analyses (7). Collectively, the current state of epidemiologic publications suggests that more incorporation of knowledge integration is needed. This conclusion is further buttressed by a significant negative trend in NCI funding for knowledge integration during the past decade. Knowledge integration is needed to ensure that we effectively manage the accumulating data on a topic and analyze the insights that can be gleaned from them to inform the direction of future research.

Lynch and Rebbeck proposed a “Multilevel Biologic and Social Integrative Construct” (2, p. 488) in which biological (e.g., genomic data) and individual (e.g., lifestyle, sociocultural, and behavioral data) factors are integrated with macroenvironmental factors (e.g., health-care policies, neighborhoods) to fully characterize the complex nature of cancer risks and outcomes. Our review showed that the multilevel approach is currently limited to studies that have investigated the interaction between a few genes and 1 risk factor (e.g., smoking). As the field becomes more integrative in nature (17) and “big data” become more prominent, this area will have to expand, and leaders may need to critically address the challenges posed by big data and determine how to actualize this framework in practice. For example, the questions of how to integrate germ-line and somatic genomic information coupled with environmental exposures will become more complicated when the macroenvironmental factors are considered.

Our review suggested that there is a critical gap in advanced translational research in cancer epidemiology, as much of the discipline’s research is anchored in the T0 (discovery) and T1 (characterization) phases. Our findings confirmed those of a previous report that only 1.8% of research in cancer genomics was conducted in the later phases of translation (18). Moving discovery research through the translational continuum is a logical framework for T0/T1

research in order to impart population impact through the subsequent T2–T4 phases. The lack of downstream translational research in cancer epidemiology may create a self-imposed boundary in the field and may inadvertently lessen its relevance to the larger scientific community. Research beyond the T0/T1 realm can extend the scope of the field, identify where epidemiologic concepts and principles can be applied, and inform guidelines and policy. However, we stress that our emphasis on translation should not diminish the importance of etiological research, nor does it imply that the conduct of more advanced translational research should fall solely on the shoulders of cancer epidemiologists.

Many of the past discoveries that have revolutionized science have been made by accident (e.g., penicillin and radioactivity); however, epidemiologic research, by virtue of its study of free-living populations in variable environments, cannot afford to rely on accidental findings. Rather, epidemiologists should engage in a thoughtful process to apply potential findings in the context of a more complex world. Our portfolio analyses also highlighted the complementary roles of the different programs within the DCCPS and DCP in supporting epidemiologic investigations across the translational research continuum. While the EGRP funds primarily etiological cancer epidemiology, other programs in the DCCPS fund more downstream translational research (T1 and beyond). This further underscores the importance of collaboration between cancer epidemiologists and investigators in other disciplines (e.g., health economics, behavioral science, health services, biology) and the need to robustly engage in team science as cancer epidemiology moves further into the 21st century.

The present findings present a cross-sectional snapshot of the types of research being conducted in cancer epidemiology and therefore do not reflect the breadth of the field. While the NCI is a significant funder of cancer epidemiology research in the United States, the grants we analyzed were reflective only of studies funded by the NCI, not of studies funded through other sources (e.g., the US Department of Defense, the Centers for Disease Control and Prevention, or private foundations). Other funders may support epidemiologic research that lies further downstream on the translational research continuum. Moreover, the NCI primarily funds US-based investigators; thus, our review did not capture the research funded by our international counterparts. It is also likely that we missed proposed applications for epidemiologic research submitted to the NCI that were transformative and that included elements of the identified “drivers” but did not score well when reviewed by the National Institutes of Health’s Study Sections and thus were not included in our analysis of funded grants. Likewise, the publications we analyzed may have reflected the work derived from funded research and/or accepted by peer reviewers but not all of the papers submitted to PubMed journals. It is possible that an evaluation of trends in submitted grant proposals and articles would suggest a different landscape with respect to the “drivers” of cancer epidemiology research. Nevertheless, such a review would have been challenging and was beyond the scope of our present analyses. The review and the findings presented reflect the funded research (in grants and publications) that successfully passed through the peer-review process at the NCI and the PubMed journals, respectively.

Limiting our analyses of literature and grants to the years leading up to and including 2010 might not have presented an accurate picture of the current landscape in cancer epidemiology. It is highly possible that there are currently more multi-institutional

collaborative publications—a direct result of more funding for consortia in 2010—that were not part of our analyses. Similarly, studies using GWAS-related technologies will have diminished, as funding for GWAS studies has dropped significantly since 2010, when more funding was allotted to post-GWAS grants. Lastly, our analyses may not have fully captured the entirety of translational research, particularly the advanced phases (T2 and beyond) of translation. It is possible that T2–T4 research may not involve the types of studies traditionally considered epidemiologic, although they may be informed by epidemiologic findings. Nevertheless, we analyzed grants supported by the DCCPS and DCP, and collectively, grants funded by these 2 divisions of the NCI should have represented a major proportion of cancer epidemiology studies conducted nationally and worldwide during the first decade of the 21st century.

The landscape of cancer epidemiology research has changed, and concrete recommendations have been made to the scientific community that, if incorporated, promise to transform the field and transition it further into the 21st century (13). While our analyses focused on cancer epidemiology, our findings provide evidence in support of such endeavors by highlighting critical areas that warrant more focused efforts by the epidemiology community at large, particularly with regard to the translational potential of a proposed study within the research continuum.

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Abbreviations

CI	confidence interval
DCCPS	Division of Cancer Control and Population Sciences
DCP	Division of Cancer Prevention
EGRP	Epidemiology and Genomics Research Program
GWAS	genome-wide association studies
NCI	National Cancer Institute
OR	odds ratio

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APPENDIX

Algorithm Used in PubMed Literature Search

The following algorithm was used to search PubMed for cancer epidemiology studies published in the years 2000, 2005, and 2010.

(Cancer[TIAB] OR leukemia[TIAB] OR lymphoma[TIAB] OR malignancy[TIAB] OR malignancies[TIAB] OR adenoma[TIAB] OR blastoma[TIAB] OR tumor[TIAB] OR tumour[TIAB] OR cancers[TIAB] OR neoplasms OR melanoma[TIAB] OR myeloma[TIAB] OR carcinoma[TIAB] OR neoplasia[TIAB] or adenocarcinoma[TIAB] OR sarcoma[TIAB] OR glioma[TIAB] OR craniopharyngioma[TIAB] OR ependymoma[TIAB]

OR Cholangiocarcinoma[TIAB]) AND (neoplasms/ep OR “epidemiology” [MeSH Terms] OR “epidemiologic methods”[MeSH Terms] OR epidemiology[Text Word] OR “prospective cohort” OR “multi-cohort” OR “multiple-cohort” OR “retrospective cohort” OR ((patients OR cases) AND controls) OR ((retrospective[Text Word] OR prospective[Text Word] OR “cross-section” [Text Word] OR “cross-sectional” [Text Word] OR “case-control” [Text Word]) AND (cohort[Text Word] OR studies[TIAB] OR study[TIAB])) OR “randomized controlled trial” [TIAB] OR ((patients OR “patient group” OR women OR men OR participants OR adult OR children) AND ((matched pairs AND tissue) OR retrospective OR retrospectively OR prospectively OR prospective OR “clinical trial” OR “clinical trials” OR “p<0.” [TIAB] OR (correlation[Text Word] AND study[TIAB]) OR cohort OR cohorts OR protocol OR population OR “control subjects” OR “healthy subjects” OR “all patients” OR individuals OR eligible OR randomly assigned OR (series AND cases) OR “odds ratio” OR “hazards ratio” OR “relative risk” OR data OR positive predictive value OR “receiver operating characteristic” OR “z statistic”)) OR (“Genome-Wide Association” OR GWAS OR “meta-analysis” OR “meta-analyses” OR “random-effect model” OR “systematic review” OR IARC) OR ((“Phase 1”[Text Word] OR “Phase I”[Text Word] OR “Phase II”[Text Word] OR “Phase 2” [Text Word] OR “phase III”[Text Word] OR “phase 3”[Text Word]) AND (study[TIAB] OR trial[TIAB])) OR “univariate analysis” OR “multivariate analysis” OR “positive predictive value” [Text Word] OR “negative predictive value” [Text Word] OR “odds ratio” OR “causal association” OR “population based” OR “Kaplan Meier”) NOT (Comment[pt] OR Case Reports[pt] OR Editorial[pt] OR News[pt]) AND “2000”[PDAT]*

For the years 2005 and 2010, “2005[PDAT]*” and “2010[PDAT]*” were substituted for the last element of the query.

Table 1

Distribution of National Cancer Institute–Funded Grants and Cancer Epidemiology Publications With Respect to "Drivers" of Translational Cancer Epidemiology and Corresponding Subcategories for the Years 2000, 2005, and 2010

Driver	NCI[a]-Funded Grants[b]						Literature (No. of Publications)[c]		
	2000 (*n* = 163)		2005 (*n* = 226)		2010 (*n* = 202)				
	No.	%[d]	No.	%	No.	%	2000 (*n* = 100)	2005 (*n* = 100)	2010 (*n* = 100)
Emerging technologies									
None	108	66.3	115	50.9	90	44.6	73	74	69
Yes[e]	55	33.7	111	49.1	112	55.5	27	26	31
Candidate gene study	28	17.2	58	25.7	43	21.3	14	16	21
Genome-wide association study	0	0	0	0	11	5.5	0	0	2
Other "-omics"-based technology[f]	3	1.8	18	8.0	28	13.9	3	1	7
GIS or geospatial analysis	1	0.6	5	2.2	0	0	1	0	0
Novel methods, models, or assays	22	13.5	21	9.3	24	11.9	10	9	1
Nonmolecular technology[g]	1	0.6	9	4.0	6	3.0	1	0	0
Collaboration/team science									
None	123	75.5	138	61.1	121	59.9	91	94	87
Cohort study	20	12.3	41	18.1	29	14.4	9	6	8
Consortium study	20	12.3	47	20.8	52	25.7	0	0	5
Translation[h]									
None	43	26.4	29	12.8	23	11.4	27	17	19
T0	82	50.3	138	61.1	126	62.4	60	65	71
T1	16	9.8	42	18.6	34	16.8	6	10	6
T2	6	3.7	8	3.5	8	4.0	1	5	1
T3	6	3.7	5	2.2	6	3.0	4	3	1
T4	10	6.1	4	1.8	5	2.5	2	0	2
Multilevel approach									
None	129	79.1	188	83.2	160	79.2	94	95	89
Gene × environment interaction	16	9.8	24	10.6	29	14.4	1	3	10
Other	18	11.0	14	6.2	13	6.4	5	2	1

Driver	NCI[a]-Funded Grants[b]						Literature (No. of Publications)[c]		
	2000 (*n* = 163)		2005 (*n* = 226)		2010 (*n* = 202)				
	No.	%[d]	No.	%	No.	%	2000 (*n* = 100)	2005 (*n* = 100)	2010 (*n* = 100)
Knowledge integration									
None	145	89.0	214	94.7	198	98.0	74	82	81
Narrative review							17	15	5
Systematic review/meta-analysis	3	1.8	2	0.9	1	0.5	3	3	11
Other	15	9.2	10	4.4	3	1.5	6	0	3

Abbreviations: GIS, geographic information system; NCI, National Cancer Institute.

[a] Grants from the NCI's Division of Cancer Control and Population Sciences and Division of Cancer Prevention.

[b] Only new and competing grants funded by the NCI.

[c] Published studies identified via PubMed and randomly selected from a set of 1,710 articles.

[d] Percentages in some sections of the table may not total 100 because of rounding.

[e] Categories are not mutually exclusive (i.e., a study could have used more than 1 type of emerging technology).

[f] Includes telomere characteristics, microRNA, mtDNA, proteomics, metabolomics, microbiomes, and copy number variation.

[g] Includes imaging technology, Web-based exposure assessment, electronic medical records, and nanotechnology.

[h] Phases of translation: T0, discovery; T1, characterization; T2, evaluation; T3, implementation and health services; T4, outcome research (6).

Table 2

Adjusted Odds Ratios[a] for Incorporation of Selected "Drivers" of Translational Cancer Epidemiology Into National Cancer Institute[b]–Funded Grants, by Study Design, 2000, 2005, and 2010

Driver	Study Design							
	Cohort-Based Grants (*n* = 90)			Consortium-Based Grants (*n* = 119)			Neither[c] (*n* = 382)	
	OR	95% CI	*P* Value	OR	95% CI	*P* Value	OR	95% CI
Emerging technologies	1.62	0.99, 2.67	0.056	1.79	1.13, 2.82	0.012	1	Referent
Multilevel approaches	2.02	1.15, 3.54	0.014	2.01	1.18, 3.42	0.010	1	Referent
Knowledge integration	1.43	0.50, 4.11	0.500	2.57	1.06, 6.20	0.036	1	Referent

Abbreviations: CI, confidence interval; DCCPS, Division of Cancer Control and Population Sciences; DCP, Division of Cancer Prevention; NCI, National Cancer Institute; OR, odds ratio.

[a] Adjusted for year of funding (2000, 2005, or 2010) and NCI division/program (DCCPS or DCP).

[b] Grants from the NCI's DCCPS and DCP.

[c] Grants to single-institution studies that were not using or generating data from cohorts or multi-institution consortia.